

REMARKS

By this response claims 1, 4, 7, 19, 26, and 30 have been amended and claims 32-35 have been added. Claims 1-7 and 9-35 remain pending. Reconsideration of the application as amended is respectfully requested.

Rejections under 35 USC §112

Claims 19-31 have been rejected under 35 USC §112. Specifically, the Examiner submits that the phrases "exposure of the oxide layer to the silicon containing gas does not add additional thickness to the oxide layer" and "exposure of the oxide layer to the silicon containing gas does not result in the formation of another layer over the oxide layer" are not described in the original specification.

Paragraph 18 recites "[t]reating the surface of the silicon dioxide with silane has been found to enhance the adhesion between the silicon dioxide dielectric and a ruthenium metal layer formed on the dielectric *without adding additional thickness.*" Paragraph 18 further describes that the treatment possibly changes "a hydroxyl-terminated surface of the dielectric to a hydrogen-terminated surface which forms a more secure bond with the ruthenium metal layer" and does not indicate a thickness increase or formation of an additional layer.

The abstract states that "[t]reating the dielectric layer with a silicon-containing gas enhances adhesion between the dielectric and the ruthenium *without requiring the addition of a separate adhesion layer* between the dielectric layer and the ruthenium metal layer."

Paragraph 6 lists reasons why the formation of an additional layer is to be avoided.

FIG. 1 depicts a wafer substrate assembly prior to exposure, and FIG. 2 depicts the FIG. 1 wafer after forming a ruthenium metal layer 36 and a protective layer 38. No thickness increase to oxide 32, or formation of a layer between oxide 32 and ruthenium 36 is depicted.

Thus it is submitted that the application as filed reasonably conveys to one skilled in the relevant art that the inventors, at the time the application was filed, had possession of the claimed invention. The material in question is stated in the text as filed and depicted in the drawings. Thus the rejection under 35 USC §112 is respectfully traversed.

Rejections under 35 USC §102

Claim 1 has been rejected under 35 USC §102(b) as being anticipated by Sashida, et al. (US Pub. 2001/0012659). Referring to FIGS. 5B, 5C and ¶72, Sashida recites forming a first oxide film 6 (ferroelectric oxide), using silane to form an oxide film 15 (TEOS), etching a window 16 through the second oxide film 15, then forming an upper electrode from ruthenium (¶58) on the on the first oxide film 6. Because Sashida is forming an oxide layer 15 using silane (SiH_4) which has no oxygen atoms, Sashida must provide some form of oxygen as a reactant within the chamber along with silane, otherwise no oxide layer could form. This oxygen is therefore a necessary reactant to form oxide layer 15.

The present invention as recited in rejected claim 1 comprises novel differences over the disclosure of Sashida. For example, claim 1 recites "forming an oxide layer" and "exposing the oxide layer to a compound consisting essentially of a silicon-containing gas selected from the group consisting of SiH_4 ...", and after exposing the oxide layer to the silicon-containing gas and *without prior exposure of the oxide layer to oxygen*, forming a ruthenium metal layer to contact the oxide layer". In contrast to claim 1 recites "without substantial prior exposure of the oxide layer to oxygen," Sashida must expose the oxide layer 6 to oxygen as layer 15 continues to form, otherwise layer 15 would not form. Without the formation of layer 15, Sashida would not expose layer 6 to silane during formation of layer 15.

Additionally, Sashida recites an oxygen anneal of oxide dielectric film 6 (¶72) prior to forming platinum (or ruthenium) upper electrode 17 to heal dielectric 6 damaged by exposure to silane. This oxygen anneal exposes dielectric film 6 to oxygen. Thus claim 1 as amended to include "without substantial prior exposure of the oxide layer to oxygen" is further novel over Sashida.

Present ¶22 discusses the deleterious effects of oxygen exposure on the treated SiO_2 surface, and the effect of minimizing its exposure to oxygen until the ruthenium metal layer is formed. Sashida intentionally treats the SiO_2 layer with oxygen to heal damage caused from exposure to SiH_4 (¶72), and also exposes it to oxygen during formation of layer 15. Thus Sashida teaches away from the present invention as claimed, specifically away from the recitation of forming the ruthenium layer on the oxide "without substantial prior exposure of the oxide layer to oxygen."

Claim 1 has been rejected under 35 USC §102(b) over Fujii (US 6,053,791). Referring to column 11 and FIGS. 19A-19C, Fujii recites the formation of a CVD silicon dioxide layer over glass to form a substrate 1 (lines 35-40), "hydrophobically" treating the substrate using a "silane coupling agent," and forming a conductive film which may be Ru (column 8 line 11).

The Examiner uses the "silane coupling agent" to teach "silane" of present claim 1. The claims have been amended to include the chemical formula for silane (SiH_4). While SiH_4 is an inorganic compound, a "silane coupling agent" may be any one of a variety of organic compounds, none of which has the formula SiH_4 . The

Examiner is referred to Exhibits I (www.powerchemical.net/coupling.htm) and II (www.micchem.com/products/SilaneCouplingAgents.htm), both printed in April, 2006, submitted with the prior response of mailed May 5, 2006 and made of record. These Exhibits provide supporting evidence that a "silane coupling agent" which the Examiner uses to reject silane does not include the compound SiH_4 . Thus claim 1 is allowable under 35 USC §102(b) for at least this reason.

Rejections under 35 USC §103(a)

Claims 4-6 have been rejected under 35 USC §103(a) as being unpatentable over Fujii, et al. in view of Terbrueggen et al. (US 2004/0053290).

Referring to column 11 and FIGS. 19A-19C, Fujii recites the formation of a CVD silicon dioxide layer over glass to form a substrate 1 (lines 35-40), "hydrophobically" treating the substrate using a "silane coupling agent," and forming a conductive film which may be Ru (column 8 line 11).

Terbrueggen recites the combination of a chemical treatment with a plasma treatment to make an oxide insulator surface hydrophobic or hydrophilic while leaving non-oxide surfaces such as gold uncontaminated (¶172). In particular, Terbrueggen states that "silanes can be used to make the oxide insulator surfaces hydrophobic or hydrophilic depending on the type of silane that replace the O-H bonds in the aqueous solution" (¶177).

Because Terbrueggen advocates a choice between silanes, Terbrueggen is not necessarily referring to SiH_4 , and is not found where the reference indicates the use of SiH_4 . It is not evident that Terbrueggen discusses or suggests specific silanes, thus the combination of Fujii and Terbrueggen would appear to result in the use of the silane coupling agents discussed in Fujii. However, SiH_4 is an inorganic compound, while a "silane coupling agent" may be any one of myriad organic compounds, none of which has the formula SiH_4 . As discussed relative to the rejections under 35 USC §102, Exhibits I and II previously submitted and of record provide evidence that a "silane coupling agent" is not silane.

Because neither Fujii nor Terbrueggen discusses the exposure of an oxide layer to one of the claimed silicon-containing gasses or the mechanism for treatment of their layers with the materials they do suggest, it cannot be assumed that they perform the invention as recited in claim 1, which recites conversion of "a surface termination of the oxide layer from a hydroxyl-terminated surface to a hydrogen terminated surface." Thus claim 4 and rejected claims 5 and 6 which depend therefrom, are allowable over Fujii and Terbrueggen in combination.

It is further submitted that the combination of Fujii and Terbrueggen to result in the present invention is possible only in hindsight using the present claims as a blueprint, which is impermissible. Terbrueggen discusses specific uses to "enable selective wetting of chemical and biological fluids on the chip surface or to prevent

or allow sticking of a given species of solution to the surface of the chip" (¶172). Thus the "solutions" referred to by Terbrueggen appear to be fluids, particularly biological fluids (¶62). Fujii's process is directed to forming wiring on glass substrates. Thus one of ordinary skill in the art would not consult a reference for preventing or enabling adhesion of biological fluids for techniques to form wiring on glass substrates.

Further, Terbrueggen's process requires the combination of a chemical treatment with a plasma treatment and, possibly, and additional plasma cleaning process (¶172). In ¶171, Terbrueggen appears to indicate that an oxygen plasma is required, thus Terbrueggen teaches away from the present invention as claimed, for example at least the recitation "without substantial prior exposure of the oxide layer to oxygen..." because of intentional oxygen exposure the oxygen plasma. Because this oxygen plasma treatment appears to be required, the combination of Fujii and Terbrueggen would also require this treatment. Thus claims 4-6 are further allowable over the combination of references as applied by the Examiner.

As discussed above, Fujii recites treatment using a silane coupling agent, while Terbrueggen recites the use of "silanes." Neither discusses the use of SiH_4 . As Fujii and Terbrueggen in combination do not teach or suggest all of the limitations of claims 4-6 (MPEP §706.02j), and the combination of references is possible only in hindsight using the present claims as a blueprint, the rejected claims are allowable over the combination under 35 USC §103(a).

Claims 2-3 have been rejected under 35 USC §103(a) over Sashida as applied to claim 1, and further in view of ordinary skill in the art. As discussed with reference to the rejections under 35 USC §102, Sashida recites forming a first oxide film 6 (ferroelectric oxide), a second oxide film 15 (TEOS) using silane, etching a window 16 through the second oxide film 15, then forming an upper electrode from ruthenium (¶58) on the on the first oxide film 6 (FIGS. 5B, 5C and ¶72). Because Sashida is forming an oxide layer 15 using silane (SiH_4), Sashida must have some form of oxygen available as a reactant within the chamber along with silane, otherwise no oxide layer could form. This oxygen is therefore a necessary reactant to form oxide layer 15, which therefore exposes layer 6 to oxygen. Thus the claim 1 recitation "without substantial prior exposure of the oxide layer to oxygen, forming a ruthenium metal layer to contact the oxide layer" is not met, as the oxide layer 6 is exposed to oxygen during the formation of layer 15 (which is prior to forming the ruthenium layer).

The present invention as recited in rejected claim 1 comprises novel differences over the disclosure of Sashida in view of ordinary skill in the art. For example, claim 1 from which claims 2 and 3 depend recites "forming an oxide layer" and "exposing the oxide layer to a compound consisting essentially of a silicon-containing gas selected from the group consisting of silane..., and after exposing the oxide layer to the silicon-containing gas and without prior exposure of the oxide layer to oxygen, forming a ruthenium metal layer to contact the oxide layer". While claim 1 recites "without substantial prior exposure of the oxide layer to

oxygen," Sashida requires a source of oxygen, otherwise layer 15 would not form, and without the formation of layer 15 Sashida would not expose layer 6 to silane during formation of layer 15. Sashida also recites an oxygen anneal of oxide dielectric film 6 (§72) prior to forming platinum (or ruthenium) upper electrode 17 to heal dielectric 6 damaged by exposure to silane. Thus claim 1 as amended to include "without substantial prior exposure of the oxide layer to oxygen" is novel over Sashida.

Present §22 discusses the deleterious effects of oxygen exposure on the treated SiO₂ surface, and the effect of minimizing its exposure to oxygen until the ruthenium metal layer is formed. Sashida intentionally treats the SiO₂ layer with oxygen to heal damage caused from exposure to SiH₄ (§72). Thus Sashida teaches away from the present invention as claimed, specifically away from the recitation of forming the ruthenium layer on the oxide "without substantial prior exposure of the oxide layer to oxygen." Thus claims 2 and 3 are allowable at least because they depend from an allowable base claim.

Claims 2 and 3 are further allowable over Sashida in view of ordinary skill in the art. As stated in the specification (§22), the maximum waiting times are to prevent exposure of the silane-treated dielectric to environmental oxygen. Sashida intentionally exposes the dielectric to oxygen during the oxygen anneal described in §72, thus there is no need for maximum allowable waiting times prior to formation of the upper electrode. Thus claims 2 and 3 are further allowable over Sashida in view of ordinary skill in the art.

Claims 7 and 9-31 have been rejected under 35 USC §103(a) over Kuroiwa (US 6,187,622) in view of Sashida. Kuroiwa recites forming a conductive layer within a hole 110a and over an insulation layer 110, then etching back the conductive layer using RIE to form a conductive plug 111. The conductive layer may be formed from a metal such as tungsten, titanium, tantalum, etc., or may be formed from polysilicon doped with phosphorous (column 8, lines 34-42).

Forming the plug 111 from polysilicon comprises flowing silane gas (SiH₄) to fill the opening 110a with polysilicon. After forming the plug, a lower electrode 114 is formed in electrical contact with the plug 111, for example from ruthenium (column 8 lines 34-column 9 line 1).

If the plug 111 is formed from polysilicon using silane, a diffusion-prevention layer 133 made from titanium is formed to cover the plug 111 and the oxide layer 110 as depicted in FIG. 2 so that the lower electrode 114 does not contact the plug 111. This prevents diffusion of silicon into the lower electrode (col. 8 lines 45-50), and also separates ruthenium layer 114 from oxide 110. With Kuroiwa, a lower electrode 114 of ruthenium will not contact the insulation layer 110 unless the plug is formed from something other than polysilicon, in which case the insulation layer will not be exposed to silane. Thus the present recitation "flowing a ruthenium metal precursor into the deposition chamber to form a ruthenium metal layer *on the oxide layer*" recited in claim 7 is not met because of intervening layer 133. (Similar

recitations are found in rejected independent claims 19, 26, and 31.) The Examiner states on page 7, lines 4-6 that Kuroiwa recites forming "ruthenium metal layer 114...on the insulating layer" 110. It is clear, however, from FIG. 2 and col. 8 lines 45-50 that ruthenium layer 114 is not formed on layer 110, but is separated therefrom by the formation of layer 133. If the plug 111 is formed from one of the other suggested materials, the oxide layer 110 will not be exposed to SiH_4 , as Kuroiwa only uses it during polysilicon formation. It should be noted that ¶31 of the present application defines the term "on" used with respect to two layer, one "on" the other, as "at least some contact between the layers." Kuroiwa intentionally separates layer 111 from 114 so that there is no contact, which results in no contact between ruthenium 114 and oxide 110.

Claim 14 is further allowable over Kuroiwa and Sashida in combination, as it recites that "subsequent to the exposure of the oxide layer to the silicon-containing gas the oxide layer is not thicker than prior to the exposure to the silicon-containing gas, and the exposure to the silicon-containing gas does not form a separate layer of material on the oxide layer." Kuroiwa forms a polysilicon layer 111 resulting from the exposure, and Sashida forms an oxide layer 15. Thus the recitation that "exposure to the silicon-containing gas does not form a separate layer of material on the oxide layer" is not met.

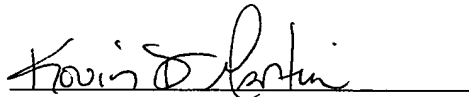
Claim 21 is further allowable over Kuroiwa and Sashida in combination. Claim 21 recites "...maintaining the semiconductor wafer substrate assembly at a temperature of between about 150°C and about 350°C during the flow of the silicon-containing gas into the deposition chamber...". Kuroiwa flows SiH_4 into the chamber to form a polysilicon layer, but does not state a temperature. Kuroiwa flows SiH_4 specifically so that polysilicon will form. However, at the temperature range specified in claim 21, polysilicon is not likely to form. Exhibit III (<http://www.semiconfareast.com/polysilicon-deposition.htm>) previously submitted with the prior response of May 5, 2006 and of record indicates that polysilicon formation using decomposition of silicon requires a temperature of between 580°C to 650°C, which is well outside the claimed temperature range of about 150°C and about 350°C. Exhibit III states that at "reduced pressure levels for VLSI manufacturing, polysilicon deposition rate below 575 deg C is too slow to be practical" (penultimate paragraph). While the Examiner states that the claimed temperature range is "taken to be obvious," it is submitted that Kuroiwa cannot use the stated temperature range, because polysilicon would not form. There is no motivation to use the stated temperature, which would in fact prevent the formation of the polysilicon, which is the reason for Kuroiwa performs the process. With the present invention as claimed, formation of polysilicon or another layer during the exposure to the silicon-containing gas is not desired, so the lower temperature may be used. Thus claim 21 is further allowable over Kuroiwa and Sashida in combination.

Any claim not individually addressed is allowable at least because it depends from an allowable base claim.

Conclusion

Thus it is believed that the present claims are in condition for allowance. If there are matters which may be addressed through a telephone conversation, the Examiner is cordially invited to contact the undersigned. This is believed to be a complete response to the Examiner's office action.

Respectfully submitted,

A handwritten signature in black ink, appearing to read "Kevin D. Martin", is written over a horizontal line.

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